

Abstract

This final report will summarize research that relates to human behavioral health and performance of astronauts and flight controllers. Literature reviews, data archival analyses, and ground-based analog studies that center around the risk of human space flight are being used to help mitigate human behavior and performance risks from long duration space flights. A qualitative analysis of an astronaut autobiography was completed. An analysis was also conducted on exercise countermeasure publications to show the positive affects of exercise on the risks targeted in this study. The three main risks targeted in this study are risks of behavioral and psychiatric disorders, risks of performance errors due to poor team performance, cohesion, and composition, and risks of performance errors due to sleep deprivation, circadian rhythm. These three risks focus on psychological and physiological aspects of astronauts who venture out into space on long duration space missions. The purpose of this research is to target these risks in order to help quantify, identify, and mature countermeasures and technologies required in preventing or mitigating adverse outcomes from exposure to the spaceflight environment.

**Astronaut Biography Project for Countermeasures of
Human Behavior and Performance risks in Long Duration
Space Flights**

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I. Introduction

The Behavioral Health and Performance (BHP) group performs integrated research to reduce adverse outcomes in three risk areas for future long duration human space flight missions. The BHP mission is to develop countermeasures to reduce and/or eliminate as many of the three major behavioral and performance risks of human space flight as possible prior to the mission, during the mission, and after the mission. The three main risks targeted within the BHP group include: the Risk of Behavioral and Psychiatric Disorders (BMed), the risk of Performance Decrement due to Inadequate Team Cooperation, Coordination, Communication, and Psychosocial Adaptation within a Team (Team), and the risk of Performance Errors due to Sleep Deprivation and Circadian Rhythm Desynchronization (Sleep). These three risks focus on the psychological and physiological aspects of astronauts who venture out into space that may be problematic on long duration space missions. The purpose of research conducted in this area is to target these risks in order to help quantify and identify the associated risk factors, and then develop and mature countermeasures and technologies required in preventing or mitigating adverse outcomes from exposure to the spaceflight environment.¹²

If the occurrences of the three risks areas that are identified by the BHP group are reduced by conducting and completing the necessary research in order to reduce the risk factors associated with each topic area within BHP, astronaut individual performance and crew performance on long-duration isolated missions can remain at an optimal level. One step in understanding the type of research that is needed in order to ensure proper risk factors are

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mitigated is to quantify historical incidents to date in order to establish baseline rates. Unfortunately, many incidents related to behavioral health and performance are largely anecdotal. However, it is possible to build an archival repository of these anecdotal incidents to help build a strong foundation for these risk factors. The astronaut biography project was designed to collect data incidents from astronaut autobiographies and record them into a database. This database will later be used as objective proof of incidents related to behavioral health and performance during spaceflight missions and will also aid in the integration of three risks areas. This integration will also demonstrate how often a problem in one of these risk areas can very well affect the others. The outcome of this data collection effort will also help inform future research tasks that are conducted within the Behavioral Health and Performance Element.

In this astronaut biography project, qualitative analyses were conducted on astronaut autobiographies and other research publications that were based on long duration space expeditions. This project will be discussed in further detail later in the report. Examples of outcomes for each of the three risk areas include: negative emotions, positive emotions, stressful situation, and interpersonal conflict. Other categories included in the coding of the events associated with the key word were causes, context, people involved that were representative of each of the BHP risk areas.

A review was conducted, prior to completing this autobiography project, on *Human Health and Performance Risks of Space exploration missions*, edited by Jancy C. Mcgee Ph.D. and John P. Charles Ph.D. This book on space exploration risks was reviewed to gain a better understanding of the BHP research group risk areas of human space flight. This review was also needed to code events using the lists of key words, place content in the proper categories, and to identify the appropriate risk areas they belong to. Another project that was completed involved the review of exercise articles that are related or have been shown to be relevant to behavioral health and performance outcomes. This review of exercise is relevant because it identifies benefits for behavioral health by utilizing exercise as a countermeasure for adverse behavioral conditions. A summary of the work completed with this project is also provided below.

II. Astronaut Biography Project

The astronaut biography project was designed to collect data of incidents from astronaut autobiographies and record them into an Excel spreadsheet. This database will later be used as objective proof of incidents related to behavioral health and performance during spaceflight missions and will also aid in the integration of three risks areas. This integration will also demonstrate how often a problem in one of these risk areas can very well affect the others. The outcome of this data collection effort will also help inform future research tasks that are conducted within the Behavioral Health and Performance Element.

Methods

To complete this project, the first step was to create a key word list to identify risk factors of behavioral health and performance. Key word lists were created for each research area (BMed, Team, Sleep). Each area had approximately 20-25 words. A BHP Research colleague compiled

a list of the relevant astronaut biographies which would be searched for these keywords. Utilizing Google Books, this colleague identified whether or not electronic versions are available to expedite the search for key terms. The biographies were rank-ordered based upon relevancy using the numbers one through three, one being most relevant and three being least relevant. This was done in order to determine which biographies to tackle first. Any of the books that were available on Google Books are to be complete first due to the ability to search the entire book electronically. Beyond that, rankings were decided based on internet reviews of each autobiography from individuals who had previously read the book. Along with those reviews, any summaries and/or outlines of the books were taken into consideration for the ranking of relevance. Once the searching of key words began via Google Books, the page numbers where various pre-determined search words appear in each of the electronic books and print copies were recorded into the initial spreadsheet.

The terms were all deposited into an Excel spreadsheet with the corresponding page numbers for each particular book. The key terms used in the spreadsheet were terms that related to each of the three risks areas (Behavioral Medicine, Team, and Sleep). These terms were organized by coding the surrounding context in that particular autobiography according to which risk area(s) the described event belonged to. The content was further classified into subgroups that identified emotional feelings represented in the content, whether it was positive or negative, a stressful situation, or an interpersonal conflict. The subgroup classifications also included the cause, who was involved, the type of event that took place, and the expedition and shuttle numbers. All of the results listed in these subgroups are to be used as gathered quantifiable data to show common preceding circumstances and common outcomes of incidents or events where certain risks in the BHP focused risk areas occurred. If the astronaut mentioned a task related to a mission or repercussions that derived from a mission completed it was recorded as applicable to common risk factors or events related to human space flight.

Analyses

This project mainly provides qualitative analyses for future understanding of risk mitigation. In the time period allotted only one book was analyzed utilizing this method, only qualitative review is possible (Note: more books were analyzed by other colleagues before this one). For example, in *Magnificent Desolation* (Aldrin, 2009), there were several entries with the key terms that showed a psychological need for an astronaut to have planned goals for after spaceflight or after their astronaut career. The reason that it was needed is so that they do not lose the feeling of structure in their life and so that they continue to have a meaningful goal in which to accomplish. Not having a prominent and important goal in life can lead to depression as it did in Aldrin's case. There was a good reference supporting this ideal that also included one of the "depression" key word entries on page 146 of *Magnificent Desolation*. This is where Aldrin stated, "I realized that I was experiencing the melancholy of things done. Worse still, when I left NASA I had no more structure in my life. For the first time in more than forty years I had no one to tell me what to do...."^[1]

In *Magnificent Desolation* on page eighty-two with the inclusion of the key term “emotional”, Aldrin emphasized the pressures of being a public icon and not receiving emotional help from professionals. Post-mission Aldrin said, “No medical or scientific group ever analyzed the emotional after effects of space travel.... But at the time, the impact of Apollo 11 and the instant celebrity brought to us by the lunar landing took a toll on everyone in my immediate family. Besides my own frustrations and the increased tension between Joan and me, we could see the residual effects trickling down in the lives of all three of our children.”^[1] This quote along with a few others recorded in the autobiographical database stresses that having a lack of emotional communication on long duration missions can ultimately cause problems not only with the astronaut but with the astronaut’s family as well.

III. Exercise Research Articles Related to BHP Risks

Exercise plays a significant role in the cognitive performance, physical performance, psychological well-being, circadian rhythm, and physiological functions of human beings. Exercise can be related to behavior, team performance, sleep, and circadian risks in numerous ways. A continuation of implementing exercise research and exercise regimens has the ability to lead the increased reduction of risks in human spaceflight in the present time and in the future. The following is a summary of some relevant articles; the first is an in-depth look at how exercise affects behavior and electrocortical activity; the other articles provide insight regarding the influence of exercise on circadian entrainment, or synchronization, to agree in time of occurrence and work together.

Mars500, a 520 day study located in Moscow, Russia, is a simulation environment intended for astronaut preparation of future Mars exploration endeavors.² A study completed in the Mars500 isolated environment was published in the *AJP: Regulatory, Integrative and Comparative Physiology* journal (Barger, L.K. et al). The study administered paper-based mood assessments on the study participants. In preparation for the longer duration of the Mars500 study consisting of 520 days there was an experiment done over a 105 day period to test the effects of exercise on the psychological and physiological aspects on the human body. The Mars500 participants consisted of six males aged 32.7 ± 5.9 years. The test participants all took the MoodMeter assessment, in which they recorded how well a selected group of 32 adjectives described their current physical or mental state on a scale of 0 (not at all) to 5 (totally). Once a week the participants completed an incremental bicycle test until 85% maximal load was reached. Electroencephalogram (EEG) activity was recorded for 5 minutes in a seated rest position prior to exercise and 5 minutes after exercise. The EEG activity and MoodMeter assessment in combination with the bicycle exercise regimen were performed 12 days prior to isolation, four times during isolation (Days 30, 64, 77, and 99), as well as 8 days post isolation.²

It was concluded from the Mars500 data that exercise had a clear effect on mood and electrocortical activity, electric activity in the cerebral cortex or gray matter of the brain. This result was discovered by recording results from using an EEG to record the electric activity from the neurons of the brain and results from the MoodMeter assessment on several occasions before and after exercise during the Mars500 isolation period. The responses from the Mars500 crew on the MoodMeter assessment increased significantly after exercise in a positive way for the adjectives associated with the physical state and psychological state. The EEG test further supported the positive effect that exercise has on the mind and revealed significant EEG activity

in all three frequency ranges (alpha, beta-1, and beta-2).³ Several studies referenced in this article confirmed that long-term inhabitation in space results in negative effects of peripheral physiological deconditioning (ex. muscular atrophy) as well as cognitive performance, mental health, and mood. ^[3, 4, 5, 6, 7, 8]

Significant phase delays have been reported for nocturnal exercise, and significant phase advances have been reported for evening exercise. ^[9, 11] One study has reported that exercise can advance the human circadian pacemaker. The circadian pacemaker is the body internal clock that controls timing of biological functions within the body such as the sleep-wake cycle, alertness, hormone secretion, body temperature regulation, blood pressure, neurotransmitter release, and hormone release. In this study subjects who performed two bouts of cycling and rowing at a heart rate of 140 beats/min during the morning and afternoon showed a 1.6-hour advance in the peak of the plasma melatonin rhythm, whereas subjects in the non-exercise control condition averaged a 0.80-hour phase delay of the melatonin peak.¹¹ Therefore, morning exercise can cause melatonin to be released earlier in the evening and prompt the body's circadian clock to start earlier in the morning. Evening exercise will have an opposite effect causing melatonin to be released later in the evening and the circadian clock to start later in the morning. Exercise has also been reported to facilitate adaptation to nightshift work in a field study that exposed subjects to a 9-hour circadian phase delay and daytime sleep.¹⁰

Methods

A review of published journal articles was conducted to find a correlation with exercise and the BHP risks. The website EasyBib.com and Google Scholar were used to search for peer reviewed published journal articles. A list of research questions and key words were made to search for articles relevant to human spaceflight, exercise, psychological adaption, and physiological adaption. The journal articles were reviewed and the results of each research study of the articles were recorded in an annotated bibliography if the article showed links between exercise and any of the BHP Identified risks (Bmed, Team, and Sleep). The parameters of the search were the terms spaceflight, exercise, behavior, depression, sleep, circadian rhythm, and psychological performance.

IV. Conclusion

Both of the projects completed will ultimately help reduce risk associated with behavioral health and performance issues when preparing for long duration missions. The astronaut biography research is needed because getting the information from autobiographies or other anecdotal texts about the astronaut experiences is a great way to document and identify common incidences about spaceflight experiences. These common incidents can later be used to identify serious issues that may be experienced in spaceflight that are related to behavioral health and performance and then to develop optimum solutions to behavioral and performance risks of spaceflight missions in the future.

The effect that exercise has on circadian rhythm shows that exercise, when performed at the right time of day, can be an important tool in the adaption of astronauts for variant shift work hours and in the optimization of their performance. The effect exercise has on behavioral health supports the idea that exercise can have a positive influence on behavioral and electrocortical activity within the brain. Exercise is not only an important factor in physical deconditioning because it also plays a key role in circadian entrainment and behavioral health. It is important to look at all of the intrinsic effects of exercise other than the within the muscular skeletal system. Based on the articles reviewed in this report, a consistently proper exercise regimen can possibly contribute to the mitigation of some risks associated with behavior, sleep, and circadian rhythm.

These articles help emphasize the importance of exercise research in relation to these BHP identified risk areas to a great effect. On the contrary, future research should be done in regard to the effects of exercise on behavioral health risks. The research of behavioral health and performance risks associated with long duration spaceflight must be continued to prepare for even longer, more arduous missions such as Mars. It is imperative to discover as many countermeasures as possible to mitigate the risks of long duration spaceflight to continue to preserve both mental and physical health of astronauts so that they are not denied there right to longevity from any risk of spaceflight.

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